Art. VII.—*Contributions to our knowledge of Australian Earthworms.*

The Blood Vessels—Part I.

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(Plates XIV.–XVII.).

Read 8th July.

Mr. J. J. Fletcher and Professor Spencer, in their general descriptions of Australian earthworms, have dealt briefly with certain of the main features of the arrangement of the blood vessels. In connection with an extended series of investigations into the structure of Australian earthworms, which is now being carried on in the Biological Laboratory of the Melbourne University, Professor Spencer has suggested that I should undertake the portion concerned with the blood vessels. The present communication forms the first instalment of this work, and I am indebted to Professor Spencer for the use of specimens from his collection, as well as for much valuable advice during the progress of the work, further instalments of which I hope to publish shortly.

The species examined belong for the most part to the Genera Megascolides, Megascolex, Perichaeta, Diporochaeta and Cryptodrilus, and I have to thank Miss Bage, M.Sc., for the use and explanation of her lists of the names and synonyms of the specimens in the collection. I have only given descriptions of dissections in most cases, as, for the present paper, I have not examined microscopically more than three worms—viz., *Perichaeta fielderi*, *Fletcherodrilus unicus* and *Cryptodrilus gippslandicus*. Of the first of these, serial sections were taken at the anterior and tail end; of the latter two, only at the anterior end of the region of the hearts. These two were

specially selected on account of the double dorsal vessel in *C. gippslandicus*, and of the large vessels in *F. unicus*, which made the structure of valves, etc., easier to make out in detail.

Of course it is very hard, even with a dissecting microscope, to make out some of the very fine connections (especially without the aid of living specimens, which might be injected), and a later examination which I hope soon to undertake with the aid of serial sections, may disclose junctions between vessels not noticeable before, or their absence, where they were thought to exist—for instance, in the relation between the dorsal and ventral vessel in the first and last segments; and the method of ending of the supra and subintestinal at the anterior end. Bourne (11) in his paper on *Megascolex coeruleus* describes the dorsal vessel as ending abruptly at the posterior end, and breaking up at the anterior, while he states that Jacquet figures peripharyngeal commissures between the dorsal and ventral vessels, sometimes as very fine threads, so that the presence or absence of this connection is apparently not a constant feature.

Nomenclature of Vessels.

The accompanying diagrams (Plate XVI., Figs. A, B, C, D) will serve to indicate the nomenclature of the blood vessels that I propose to employ during the course of this investigation.

In none of the worms examined have I found a subneural vessel. Bourne (11) says this is absent in all the simpler, and many of the more complex forms, e.g., many, if not all, the Perichaetidae, Pontodrilus and Microchaeta. He uses the term "ventral" for the subintestinal which, he says, is constant in all Oligochaetes, evidently meaning the main ventral vessel of Australian forms, and not that which I have called subintestinal. This latter, together with my lateral, forms what he calls the Intestino-tegumentary vessels of Perrier (Rech. pour servir àl' hist. des Lombriciens terrestres," Nouv. Arch. du Mus. d'Hist. Nat. de Paris, 1872), or his latero-longitudinal vessels, which, he says, are exaggerated anterior representatives of a series of similar vessels, which occur in every segment, and to which whole series he gives the name intestino-tegumentary. He defines Hearts as those vessels which are

rhythmically contractile, circularly disposed, and which may be (1) all connected with the dorsal, or (2) some only and some with the supra-intestinal, or (3) some with the dorsal vessel only and some with both. He calls the first lateral; those which only connect with the Supra-intestinal, Intestinal; and those which connect with both Latero-intestinal. I have kept the word Heart for only those vessels which arise from the Supra-intestinal, and pass to the ventral, with or without branches from the dorsal (except in the case of *D. davallia*, where sections would probably show the connections between dorsal and supra-intestinal), and have called those passing from the dorsal to the ventral anterior to these, anterior commissural vessels. These Benham (5) also calls "lateral hearts." My supra-intestinal evidently corresponds to Bourne's dorso-intestinal, while those vessels at the extreme anterior end, which break up without joining the ventral, belong to his dorso-tegumentary system. In the post-cephalic region (Bourne 11, note page 73) the branches may be posterior commissural, or dorso-intestinal, or tegumentary, the chief difference being, in those specimens I have examined, that the anterior one arise at the posterior end of the segment, and the posterior from the middle.

The generic names employed are those given by Beddard in his "Monograph of the order Oligochaeta."

1.—Megascolides gippslandicus, Spencer.

Cryptodrilus gippslandicus, Spencer. P.R.S. Vict., 1892.

Plate XIV., Figs. 1, 1a, and Plate XVII., Fig. 20.

Dissection.—The specimen examined was broken for some distance behind segment 14. There is a *double dorsal vessel* becoming single at the tail end, the two halves alternately joining at the septa, and becoming divided on passing through them in the anterior region, and running forward thus to the front of segment 6, where they finally unite to form a single vessel, which breaks up in the first segment.

In segments 10, 11, and 12, there are no *commissural* vessels arising from the dorsal, but behind this, one main one arises on each side about the middle of the segment, and runs down to join the ventral one, sending branches to the alimentary canal on its way. In segments 9, 8, 7, 6 and 5 there are commissural vessels arising from the dorsal. That in segment 4 does not reach the ventral, but runs back as far as segment 9 as the *lateral.* In segments 10, 11 and 12 this receives a branch from the plexus on the alimentary canal, forming a *sub-intestinal* on each side.

The *ventral vessel* is single, and runs forward to the first segment, breaking up there. In segments 6, 7, 8, and 9 the vessels connecting it with the dorsal give out marked branches to the ventral body-wall before joining it. The *supra-intestinal vessel* arises from the dorsal posteriorly in segment 12, and runs forward to the front of 8. It gives off three pairs of *hearts* in 10, 11 and 12, and in these segments also are marked branches to the alimentary canal arising from the supra-intestinal and running round to join the sub-intestinal. Professor Spencer (15) describes six pairs of hearts in segments 6-12. His anterior ones are evidently in this as in other cases, those I have called anterior commissural.

Sections.—The blood supply in one segment in the region of the hearts, as reconstructed from serial sections, is seen to be complicated. At each mesentery the double dorsal vessel unites to form a single one. At the point of junction a valve (Fig. 20 v.) is formed, and the vessels there divide again. In the hinder part of each segment the supra-intestinal unites with the vessel formed by the union of the two hearts of the segment, at which point a valve is placed; and the supra-intestinal runs forward to the next segment, giving off marked vessels to the alimentary canal, on whose walls is formed a close plexus.

The ventral vessel in each segment receives the heart, the junction being guarded by a valve, and just before the point of union a branch is given off to the ventral body wall and nephridia (Fig. 20, Af. Ne)—the ventro-tegumentary of Bourne. A short distance up, the heart, which is here much smaller in section than on the dorsal surface, gives off from a valved

opening a branch to the sub-intestinal vessel (Fig. 20). From the alimentary canal a vessel passes on each side uniting in the middle line (Fig. 20, M.V.), and then passing to the sub-intestinal as a single vessel on each side. Close to this opens a branch from the ventral body wall and nephridia (Fig. 20 Ef. Ne). Since that to the excretory organs is given off from the heart just before the latter joins the ventral vessel, the blood is propelled to them with the full force of the contraction of the heart. This agrees with Bourne's (11) description of the course of the blood supply to the large nephridia, and with Benham's (6) of that in Lumbricus, though these two authors are not at one as to the course of the blood through these vessels.

2.—Megascolex goonmurk, Spencer.

Perichaeta goonmurk, Spencer. P.R.S. Vict., 1892.

Plate XIV., Figs. 2, 2a.

Dissection.—The dorsal vessel is double (Fig. 2a, D.D.V.) along the greater part of its length, but thirty-one segments from the posterior end it becomes single, and at each mesentery the two halves unite as far forward as the front of segment 10, then remain double till the front of 5, where they unite to divide again, joining at the front end, and giving off a *commissural vessel* on each side to join the *ventral*, which is single along the whole length of the body. It is united with the dorsal by a pair of commissural vessels in each segment at the posterior end, and this arrangement is continued forward as far as segment 13. From the posterior part of segment 12 the dorsal gives off a supra-intestinal which runs forward to the front of 9, giving off in segments 10, 11 and 12 a pair of *hearts* posteriorly in each segment, which run round and join the ventral vessel. I have been unable to find the double supra-intestinal vessel described by Professor Spencer in this form (13). From 9-5 the dorsal gives off in the posterior part of each segment a pair of commissural vessels, and in 4 one which, after running a short distance, divides into two, one passing forward to the cerebral ganglion to form part of the intestino-

tegumentary plexus of Bourne; and one back as the *lateral* at first, and then as the *sub-intestinal* one each side, and ending on the posterior septum of 13. This vessel receives, in segments 9, 10, 11 and 12, branches from the alimentary canal which derive their blood from the supra-intestinal, and in segments 5, 6, 7 and 8, it gives off branches to the ventral body wall whose origins in some cases are marked by swellings (Fig. 2, Sw.), which probably are contractile, and serve to propel the blood. Bourne (11) has also noted such muscular swellings on his "anterior lateral hearts."

3.—Diporochaeta davallia, Spencer. P.R.S. Vict., 1900.

Plate XIV., Fig. 3.

Dissection.—The dorsal vessel is single, swollen in segments 13-15, and running forward to the first segment, where it divides into two, and joins the ventral one. At the posterior end of the body the dorsal and ventral are connected by a *commissural vessel* on each side, and this arrangement is continued forward, in segment 15 there being two such connections in the specimen examined. From the hinder part of segment 13 the dorsal gives off a *supra-intestinal* running forward to the front of 10, and, in segments 10, 11 and 12 hearts arise from the dorsal running round to the ventral vessel, one pair in the hinder part of each segment. From 9-4 the dorsal gives off a pair of commissural vessels posteriorly in each segment, and in 4 this beanch gives rise to a *lateral* which divides into two, one half running forward and one back; the latter giving in segments 4-9 marked branches to the ventral body wall, and uniting in the anterior part of segment 10 with its fellow of the opposite side to form a *single sub-intestinal vessel* which receives branches from the alimentary canal in segments 10-12, deriving their blood from the supra-intestinal, which also gives a vessel on each side to the ventral in segment 13. The branch from the dorsal in segment 3 does not reach the ventral vessel, but the ventral becomes much branched in this region, and is single for the whole length of the body.

4.—**Megascolex tenax**, Fletcher.

Perichaeta tenax, Fletcher. P. Linn. Soc., N.S.W., vol. ii., 1887.

Plate XIV., Fig. 4.

Dissection.—The dorsal vessel is single, swollen in segments 10-15, and joining the ventral by a *commissural* branch on each side, supplying the alimentary canal on the way, at the posterior end of the body. The dorsal and ventral vessels are thus connected as far forward as segment 14, there being no such vessel in segment 13. From the hinder part of each segment, from 9-5, a pair of commissurals arises, and in 9, 8, 7, and 6 each gives off marked branches to the ventral body wall (Br.W.), in some cases from a distinctly swollen patch, which probably has a propelling function (cf. similar structures in *M. goonmurk*). A well-marked vessel arises from the dorsal on each side in the posterior part of segment 4, but does not reach the ventral, dividing instead into two, one of which runs forward to segment 1, in which dorsal and ventral also break up; and the other passes as a *lateral* through segments 5, 6, 7, 8 and 9, and as a *sub-intestinal* through 10, 11, 12 and 13, ending in this last. Small vessels, only running a short distance down and then breaking up, arise from the dorsal in segments 2 and 3, forming the anterior network of the dorso-tegumentary of Bourne. A *supra-intestinal* vessel arises from the dorsal in the posterior part of segment 13, and runs forward to the front of 10. From this branches are given off on each side, supplying the alimentary canal, in segments 10, 11, 12 and 13, and joining the sub-intestinal on each side on the ventral surface. In 10, 11 and 12 *hearts* also arise from the supra-intestinal, one pair posteriorly in each segment, and pass to the ventral vessel—the anterior pair being not very conspicuous in the specimen examined.

The ventral vessel is single, running the whole length of the body, and joining the dorsal at the anterior end by a very fine branch.

5.—**Perichaeta obscura**, Spencer. P.R.S. Vict., 1892.
Diporochaeta obscura, Spencer.

Plate XIV., Fig. 5.

Dissection.—The dorsal vessel is single and swollen in segments 13-17, running the whole length of the body, and breaking up in segment 1, but connected with the ventral by a commissural vessel on each side at the posterior end of the body. It gives off from the posterior part of segment 12 a *supra-intestinal*, and from this point also a heart arises on each side. The supra-intestinal gives off a pair of hearts in segments 10 and 11, in the posterior part of the segment, and also, in 9, 10, 11 and 12, a vessel to the alimentary canal, and joins the dorsal at the front of segment 9. From 9-4 the dorsal gives off posteriorly in each segment a pair of commissurals, but in 3 this vessel does not seem to pass to the ventral surface, and in 4 it gives off on each side a *lateral* which runs back and forms the *sub-intestinal* ending on the posterior septum of 13, and receiving in segments 9, 10, 11 and 12 branches from the alimentary canal derived from the supra-intestinal.

The ventral vessel is single along its whole length, and breaks up in segment 1.

6.—**Perichaeta manni**, Spencer. P.R.S. Vict., 1900.
Diporochaeta manni, Spencer.

Plate XIV., Fig. 6.

Dissection.—Dorsal vessel single, breaking up in segment 1 and swollen in 13-17. Connected with the ventral by a *commissural vessel* on each side in 13, and giving off in this segment a *supra-intestinal*, running forward to the front of 8. In segments 10, 11 and 12 this gives rise to a pair of hearts posteriorly in each segment, and also a branch to the alimentary canal. From 9-5 the dorsal gives off commissurals in the hinder part of each segment, that in 6 sends a branch forward to 5 and back to 9, as the *lateral* to be continued in segments 10, 11 and 12, as the *sub-intestinal*. If vessels come off from the dorsal in front of 4 they are too small to trace round. The *ventral* is single, and runs forward to break up in segment 1.

7.—**Perichaeta macquariensis**, Fletcher. Proc. Linn. Soc. N.S.W., vol. iv., 1889.

Megascolex macquariensis, Fletcher.

Plate XV., Fig. 7.

Dissection.—Dorsal vessel single and swollen in segments 10-18, running forward to break up in the first segment.

The ventral also is single, and breaks up in the first segment, giving off marked branches to the ventral body wall in segments 5, 6, 7, 8 and 9, and receiving in these segments a *commissural* vessel from the dorsal. Commissurals also arise from the dorsal from segment 13 backwards. That in 4 does not reach the ventral, but divides into two, one running forward to segment 1, and the other back as the *lateral* in 5-9, and as the *sub-intestinal* in 10, 11 and 12 in the last of which it ends. In these last three it gives off vessels ending on the posterior septum of the segment. Bourne (11) also remarks that in *M. coeruleus* the anterior of his lateral hearts do not reach the ventral vessel, but give off branches to connect with the intestino-tegumentary system.

A supra-intestinal arises from the dorsal vessel posteriorly in segment 12, and runs forward to the front of 10, giving off in 10, 11 and 12, in the hinder part of the segment, a pair of *hearts*, which pass to the ventral vessel, and also from this vessel branches arise which supply the alimentary canal and join the sub-intestinal.

8.—**Perichaeta valida**, Fletcher.

Plate XV., Fig. 8.

Dissection.—Single dorsal vessel, swollen in segments 13-16, less so in 12-9. From 13 backwards it gives off a *commissural* vessel in each segment, supplying the alimentary canal on the way, and this arrangement is continued to segment 13 in which there is no connection between the dorsal and ventral. These latter both run forward, breaking up and apparently joining in segment 1, and the dorsal gives off a *supra-intestinal* in the hinder part of 13, which runs forward to the front of 7. Commissural vessels arise from the dorsal in 9-4, and reach

the ventral, but that in 3 turns back and runs to the posterior mesentery of 13 as the *lateral*, as far as 9, and afterwards as *sub-intestinal*, giving off in 4 a branch running forward to segment 1. There is a very strongly marked development of blood vessels on the wall of the alimentary canal in segment 5, and in 7, 8 and 9 a branch arises from the supra-intestinal and breaks up on the wall of the oesophagus. In segments 10, 11 and 12 this vessel joins the sub-intestinal. *The hearts* are 3 pairs, arising from the supra-intestinal posteriorly in segments 10, 11 and 12, and run round to join the *ventral*, which passes along the whole length of the body, breaking up in segment 1.

9.—**Diporachaeta richardi**, Spencer.

Perichaeta richardi, Spencer. P.R.S. Vict., 1900.

Plate XV., Fig. 9.

Dissection.—Dorsal vessel single, swollen in 13-15, and breaking up in segment 1. At the posterior end it seems to be connected as in other forms with the ventral, but the latter is here very small. Professor Spencer (14) describes the dorsal as breaking up in the second or third segment. The dorsal gives off a supra-intestinal posteriorly in segment 12, which runs forward to the front of 10, giving rise, in the hinder parts of segments 10, 11 and 12, to pairs of hearts to join the ventral, and a vessel on each side to the alimentary canal. In segments 5, 6, 7, 8 and 9, the dorsal gives off *commissurals*, that in 5 sending a branch back as the *lateral*, at first and, later, as the *sub-intestinal* on each side which receives branches in 10, 11 and 12 from the alimentary canal. If the dorsal gives off any vessels in front of 5, they must be small, and break up soon. The *ventral* runs forward to segment 5, where it breaks up.

13. **Fletcherodrilus unicus**, Fletcher.

Cryptodrilus fasciatus, Fletcher, Proc. Linn. Soc. N.S.W., 1889.

Plate XV., Fig. 10, and Plate XVII., Figs. 21, 22, 23.

Dissection. Single *dorsal vessel*, very much swollen from 10-16, and running forward to divide into two in the posterior

part of segment 3, and to break up in segment 1. At the extreme posterior end *commissural* vessels, supplying the alimentary canal on the way, arise, one pair in each segment, but seven segments from the end and forward for some distance there are two of these vessels to the segment, probably one belonging to the dorso-intestinal or tegumentary system of Bourne (11). The *ventral* runs forward and ends in the first segment. There is no commissural between it and the dorsal vessel in 13, but behind this segment one main one passes round in each segment, supplying the alimentary canal on the way.

From segments 9-5 a similar vessel is found, arising as usual in the case of the anterior commissurals in the hinder part of the segment. In 4 this vessel does not reach the ventral one, but half way round it divides into three. One branch runs forward to break up definitely in segment 1; one back to end on the posterior mesentery of 13, forming the *lateral* in 5, 6, 7, on each side, and in 8, 9, 10, 11, 12 and 13 the *sub-intestinal* receiving in each of these segments vessels from the alimentary canal wall. The third branch from the commissural in 4 unites with its fellow of the opposite side in segment 4 to form a short transverse vessel under the alimentary canal.

The *supra-intestinal* arises from the dorsal in the posterior part of 13, and runs forward to the front of 8. Three pairs of *hearts* are present, one in each of segments 10, 11 and 12, arising from the supra-intestinal posteriorly in each, and receiving a small branch from the dorsal close to their point of origin.

Sections.—In the region of the hearts, the blood supply is seen to be fairly simple. In the hinder part of each segment, on either side, the dorsal vessel sends a branch, whose opening is guarded by a valve, to join the supra-intestinal, which opens by a valve (Figs. 21, 22v, 23v) into the heart (Figs. 22 and 23Ht.); and then runs on, giving various branches to the alimentary canal, forming a plexus on its walls (Figs. 22 and 23 Pl.). The heart passes to the ventral surface, and opens by a valve (v.) into the ventral vessel, which is a single tube. The blood from the plexus (Pl.) round the alimentary canal is collected into the sub-intestinal vessel (Sub. I.V.), which is double to the end of segment 13.

The nephridia are supplied by vessels opening directly from the hearts (Fig. 23 Af. Ne.), while the blood is brought back in small vessels opening into the sub-intestinal (Ef. Ne.). Benham (6), in describing the vascular supply to the nephridium in Lumbricus, says the course of the blood is along the commissural, which receives blood from the nephridia and body wall, to the dorsal, which then supplies the alimentary canal. Bourne (11) says blood passes from the nephridia to the sub-intestinal, and from the alimentary canal plexus to the dorsal vessel, in this agreeing with Vejdovsky. The valves (Figs. 21, 22a. 22b) are shown in section to be membranous, almost funnel shaped structures, stretching across the vessel, with a circular opening in the middle. The most marked sets are those in the dorsal vessel at each mesentery, which are attached to a well-marked muscular thickening on the wall; and those leading from the supra-intestinal to the hearts, which, however, do not seem to be connected with any such thickenings.

The branch from the dorsal vessel to the heart is also guarded by a similar, though very small, valve, and the whole structure has very little the appearance of a functional vessel.

In the case of the dorsal vessel the action of the valve is clearly that of guiding the blood forwards and preventing it from flowing backwards. In the event of the blood attempting to flow backwards, it is evident that the pressure of the fluid on the wall of the funnel would close the opening in the latter. The valves leading towards the hearts are so small that it is difficult to determine their exact structure and relationships. The valves guarding the entrance of the supra-intestinal into the hearts have the convex face of the funnel facing into the heart. Pressure of blood on the heart—that is, the convex side—would close the small opening in the funnel.

11.—Megascolex fielderi, Spencer.

Perichaeta fielderi, Spencer, P.R.S. Vict., 1892.

Plate XV., Fig 11, and Plate XVII., Fig. 24.

Dissection.—The *single dorsal vessel* is much swollen in segments 16-9, and runs forward to break up in the first segment. At the posterior part there is a commissural vessel supplying

the alimentary canal on the way. This arrangement apparently persists in the last segment, and is continued forward in each to the region of the swellings in the dorsal vessel.

In segments 9, 8, 7, 6, 5 and 4, a commissural arises from the back of the segment on each side. In segment 5 this vessel divides into two after a short distance, one half running forward to break up in the salivary gland; and one passing back as the *lateral*, forming a double *sub-intestinal* in 10, 11, 12 and 13, and ending in 13. In these segments it receives branches from the plexus on the alimentary canal, derived from the *supra-intestinal*, which rises from the dorsal in the hinder part of the segment 14, and runs forward to the front of segment 8, receiving a small branch from the dorsal in 10, 11, 12 and 13 on each side, and giving off from the point of junction of this in each of these segments a pair of *hearts* to the ventral vessel. The most anterior of these is smaller than the others, and there seems to be a tendency to a more than ordinary development of hearts in this species, as, in addition to the 4 pairs commonly met with in *M. fielderi*, a single heart was found in one specimen in segment 14 on the left side (cf. Beddard, 1). In 14 there seems to be no commissural, but a vessel arises from the supra-intestinal apparently ending on the alimentary canal wall.

The *ventral vessel* is single, and runs forward to break up segment 1.

Sections.—The blood supply in the heart region is fairly simple. In the interior part of each segment the dorsal vessel gives off a pair of small branches with valvular openings (Fig. 24, V.), to the supra-intestinal, and from, or close to, the junction of those two the supra-intestinal gives off a pair of hearts, their openings being guarded by valves. The hearts join the ventral vessel on its under surface by a valvular opening. The supra-intestinal gives off a branch to the alimentary canal, forming a thick plexus on its walls (Pl.), from which a main vessel passes on each side to the sub-intestinal. In the region of the hearts the nephridia are micro-nephric, and the origin of their blood supply is indefinite, but is probably from the ventral vessel or its ventro-tegumentary branches. At the hinder end, where the excretory organs are meganephric, they

seem to derive their blood from the main commissural vessel soon after its origin, branches passing to the nephridia on one side and alimentary canal on the other, all the way down the segment (compare *F. unicus*, Fig. 23, in which the nephridial vessel arises from the heart). The vessel from the alimentary canal on the ventral side is small and median, and opens into the ventral.

12.—**Megascolex dorsalis**, Fletcher.

Perichaeta dorsalis, Fletcher, Proc. Linn. Soc. N.S.W., Vol. II., 1887.

Plate XV., Fig. 12.

Dissection.—The *dorsal vessel* is single, swollen in segments 14-17, joining the central by a single *commissural* vessel on each side, at the posterior part of the body, in each segment, and dividing at the anterior end into a very fine branch on either side, running round to the ventral, which is here small. Forward from the tail end a pair of main commissurals are given off in each segment, but posteriorly in segment 13 a *supra-intestinal* arises from the dorsal, giving off a pair of hearts at its point of origin, and runs forward to break up on the alimentary canal in segment 8. In the hinder part of segments 10, 11 and 12 also, a pair of hearts arise, making four pairs in all, and each receives a small branch from the dorsal close to its origin. In 9, 10, 11, 12 and 13 the supra-intestinal gives a branch to the alimentary canal. In segments 9-6 a pair of commissural vessels rise from the dorsal, posteriorly in each segment, and pass to the ventral, giving a branch to the alimentary canal (B.A.), and ventral body wall (Br.W.) on the way. In segment 5 the commissural gives off a lateral one each side before joining the ventral, and this lateral divides into three, one branch running forward to break up, one passing under the alimentary canal to join its fellow of the opposite side, and one back as the lateral, and later as the *sub-intestinal*, which gives a branch to the septum (B.S.) in each segment from 6-12, and ending posteriorly in segment 13. The sub-intestinal receives branches from the alimentary canal, derived from the supra-intestinal in segments 9, 10, 11, 12 and 13.

The *ventral* vessel is single, occurring the whole length of the body.

13.—**Digaster excavata**, Fletcher.

Perissogaster excavata, Fletcher. Proc. Linn. Soc., N.S.W., 1888.

Plate XV., Fig. 13.

Dissection.—*Dorsal* vessel single, swollen in segments 13-15, less so in 12-10, and running forward to segment 1, where it divides into two, one branch running round to each side to join the ventral. From 19 backwards the dorsal sends a *commissural* to join the ventral in each segment, supplying the alimentary canal on the way, but from 18-14 there are two of these branches to the segment. In segment 13 the dorsal is not connected with the ventral at all, but gives off at the posterior mesentery a *supra-intestinal*, which runs forward to the end, apparently blindly, in the front of 8. Posteriorly in segments 10, 11 and 12 a pair of *hearts* arise, each having a double origin—from the dorsal and supra-intestinal vessels —and runs round to the ventral. In segments 9-4 the dorsal gives off a commissural on each side in the under part of the segment, passing to the ventral, and giving a branch to the ventral body wall (Br.W.), and back septum (B.S.) in 9-5, and in 8-5 one to the alimentary canal (B.A.). That in segment 4 gives rise to the *lateral*, which runs back as the *sub-intestinal*, and also, apparently, forward to break up in the salivary gland, but both this and its junction with the commissural vessel in segment 4 are indistinct, owing to the large development of this gland. The sub-intestinal remains distinct on each side, and runs back to segment 16, giving branches to the posterior septa of segments 13 and 14 (B.S.). It receives in 9, 10, 11, 12 and 13 vessels from the alimentary canal derived from the supra-intestinal. The *ventral* is single along its whole length, breaking up in segment 1, and receiving, as described, a branch from the dorsal in this segment.

14.—**Megascolex coxii**, Fletcher.

Perichaeta coxii, Fletcher. Proc. Linn. Soc. N.S.W., 1888.

Plate XV., Fig. 14.

Dissection.—Dorsal vessel single, swollen in segments 10-15, though not much so. It runs the whole length of the body, and in segment 1 divides into two, passing round on each side to join the ventral vessel. The dorsal and ventral are also apparently connected as usual at the posterior end, the dorsal giving off a pair of commissurals to join the ventral in each segment, as far forward as the region of the *hearts*. In 14 and 15 these branches are two in number at their origin from the dorsal, though it is not clear if both reach the ventral. This latter becomes double in segment 14 in one specimen examined, but this is probably only an individual variation, as it was not noticed in the other, nor in any other species. In the hinder part of segment 13 the dorsal gives off a pair of *hearts* to the ventral, joining it on the under side, and this arrangement is continued forward to 10, the only other worms in which four pairs of hearts were observed being *P. fielderi*, *P. dorsalis* and *C. grandis* (see Beddard, 1). That in segment 13 may be said to give rise to the *supra-intestinal*, which runs forward to the front of 7, or, the hearts may be taken as having a double origin, but the supra-intestinal does not appear to run back beyond the first pair, seeming rather to arise from the dorsal through them. From the back of 9-4 the dorsal gives off in each segment the usual *commissural vessels*, which send branches to the ventral body-wall (B.W.) in 9-6. In segment 4 the commissural gives off close to its origin a *median vessel*, which runs back to break up in a large plexus over the alimentary canal in segment 5. The whole of the anterior part of the digestive tract and the salivary glands are particularly well supplied with blood in this form, especially in segments 4, 5 and 6. In segment 3 a vessel arises from the dorsal, but appears not to reach the ventral, while from the commissural in segment 4 arises, on each side, as well as the median, a *lateral* vessel, which sends branches forwards to the salivary gland, and one backwards, forming later on the *sub-intestinal*.

In segment 6 there is an unusually large development of branches from the lateral, one supplying the alimentary canal in this segment, and two running forward to do so in the more anterior ones; while one large vessel passes to the ventral surface. In segments 6-9 the lateral gives branches to the posterior septum (B.S.) in each segment, and in 7-13 it receives branches from the alimentary canal, derived from the supra-intestinal in 13-8, and probably in 7 also, though here the latter vessel is small, and the origin of the branch to the alimentary canal indistinct, appearing in one specimen to be from the commissural vessel close to where it arises from the dorsal.

The *ventral* vessel runs the whole length of the body, uniting with the dorsal as described, and sending off a good many branches from segment 4 forwards. From 14 back it gives marked vessels to the ventral body-wall in the posterior mesenteries of the segments.

15.—Cryptodrilus hulmei, Spencer.

Megascolides hulmei, Spencer. P.R.S. Vict., 1892.

Plate XVI., Fig. 15.

Dissection.—Dorsal vessel single, running the whole length of the body. From segment 17 back it gives off a pair of commissural vessels in each segment to join the ventral, supplying the alimentary canal on the way. This arrangement is apparently continued to the posterior end, but at the very end of the body the mesenteries are so thick that the vessels, which are here small, are hard to make out. From segment 13 forward the mesenteries also become extraordinarily thickened, very much obscuring the blood supply, especially that connected with the ventral vessel. From 16 forward the branches from the dorsal become irregular. In segment 16 there are two on each side, one running to the ventral and only supplying the alimentary canal (Dorso-intestinal, Bourne). In 15 there are also two, but neither of these reaches the ventral, both ending—after supplying the alimentary canal—in the *sub-intestinal*, which ends on the posterior mesentery of this segment. The anterior pair of these vessels forms a small plexus on the roof of

the alimentary canal, and from this the *supra-intestinal* arises, which runs backwards to the posterior mesentery of 15, and forwards to the front of 8. In 13 and 14 it gives off a vessel on each side to the alimentary canal, which opens into the sub-intestinal, there being no branch from the dorsal in these segments. In segments 10, 11 and 12 a pair of *hearts* arise from the dorsal and supra-intestinal in the posterior part of the segment, opening into the ventral, markedly on its under side. In segments 9-5 the dorsal gives off posteriorly in each segment a *commissural* vessel on each side, having a small connection with the ventral, and ending clearly on the septum. From segment 9 forwards the ventral is very small indeed, and its connection with these vessels becomes more and more indistinct. It seems to break up soon after its junction with that in segment 5, but may continue to the most anterior end. In segments 4, 3 and 2 the branches from the dorsal break up on the wall of the alimentary canal, while that in 5 gives off a *lateral*, running forward and downward for a short distance, and backwards and upwards at first, then dipping down as the *sub-intestinal* on each side, ending at the back of 16 as described. From 8-14 this vessel receives branches from the alimentary canal, derived from the supra-intestinal which ends blindly in front of segment 8.

16.—Diporochaeta yarraensis, Spencer.

Perichaeta yarraensis, Spencer. P.R.S. Vict., 1892.

Plate XVI., Fig. 16.

Dissection.—Dorsal vessel single, swollen in segments 13-18, less so in 10-12. At the front end it divides and runs round, apparently joining with the ventral, but both vessels are here small. At the hinder end the dorsal and ventral are joined by a single pair of commissural vessels, one on each side. Ten segments from the last, these, in one specimen, appeared to come off, not in the middle of the segment as is the case further forward, but down the mesentery. As, however, this arrangement was less marked in the next examination, and as the muscles in the mesentery are here very thick, this appear-

ance may have been due to the vessels being covered by the muscles. In the hinder part of 13 the dorsal gives off a *supra-intestinal*, running forward to end in 8. This gives rise in the posterior part of segments 10, 11 and 12 to a pair of *hearts*, each receiving, as in many others, a small branch from the dorsal. In the same position in segments 9-4 the dorsal gives off a pair of *commissural* vessels in each segment, running round to the ventral, and giving branches to the alimentary canal (B.A.) and ventral body-wall (Br.W.) on the way in segments 9-6, and in 5 sending back a *lateral*, which is continued as a *sub-intestinal* on each side in 9, 10, 11 and 12, and which in these segments receives branches from the alimentary canal, derived from the supra-intestinal, and perhaps also in segment 8.

The *ventral* is connected with the dorsal as before described, and behind the hearts gives clear branches to the ventral body wall, being single along the whole length of the body.

17.—Diporochaeta tanjilensis, Spencer.

Perichaeta tanjilensis, Spencer. P.R.S. Vict., 1892.

Plate XVI., Fig. 17.

Dissection.—*Dorsal* vessel single, swollen in segments 13-16, and joining the ventral by a single commissural branch on each side at the posterior end of the body. This arrangement continues in each segment till 13, in which the dorsal gives off as well a *supra-intestinal*, swollen in segments 10-12, and running forward to the front of 8. The dorsal runs forward to the first segment, possibly passing to the ventral surface, but is here very small, and gives off a pair of *commissural* vessels on each side in the posterior parts of segments 9-5, those in 9-6 giving branches to the ventral body wall (Br.W.), that in 5 giving a branch running back as the *lateral* on each side, and receiving vessels from the alimentary canal, derived from the supra-intestinal in segments 8-12. A pair of *hearts* arise at the back of the segment from the supra-intestinal in 10, 11 and 12, and run round to the ventral vessel, each receiving a very small branch from the dorsal at their point of origin.

The *ventral* is single, giving off from segment 13 backwards clear vessels to the ventral body wall. This form, though not identical with *D. yarraensis*, is closely similar to it in circulatory system, as in others (compare Professor Spencer 13).

18.—Diporochaeta copelandi, Spencer.

Perichaeta copelandi, Spencer. P.R.S. Vict., 1892.

Plate XVI., Fig. 18.

Dissection.—Dorsal vessel single, swollen in segments 10-17, and breaking up in segment 1. It is connected with the ventral by a pair of commissural vessels in each segment, as far forward as 14, and gives out in the hinder part of segment 13 a *supra-intestinal*, which runs forward to break up in 8. From the back of 10, 11 and 12 this receives a small branch from the dorsal on each side, and from the junction of the two a pair of *hearts* arise in each segment, or, as in most cases in which there is a branch from the dorsal in these segments, the hearts may be regarded as having two points of origin. The hearts run round to join the ventral vessel, and from segments 9-5 the dorsal gives off from the back of the segment a pair of commissural vessels, which do likewise. In 5 this vessel is very small and indistinct, and in 6 it runs through a curious glandular structure. In 7 it seems to give off backwards, from the middle of a similar gland, a *lateral* vessel on each side. In 10 these become the *sub-intestinal*, and that of the right side sends a branch to that of the left, running on for a short distance, and then disappearing, while the left continues as the single sub-intestinal, ending in the posterior part of segment 13, and receiving in 10, 11, 12 and 13, branches from the alimentary canal, derived from the supra-intestinal.

The *ventral* vessel becomes very small at the anterior end, and does not appear to unite with the dorsal. It gives off branches to the posterior system of the segment from 14 backwards.

19.—Diporochaeta bakeri, Fletcher.

Perichaeta bakeri, Fletcher. Proc. Linn. N.S.W., vol. ii., 1897.

Plate XVI., Fig. 19.

Dissection.—Dorsal vessel single, running forward to break up in segment 1, and joining the ventral by a commissural vessel on each side at the most posterior end. It is swollen in 10-17, and connected with the ventral by a pair of *commissurals* in each segment, till the posterior part of segment 12, where it gives off a *supra-intestinal*, running forward to break up in 8. The supra-intestinal apparently receives a small branch from the dorsal on each side in 10 and 11, and in 10, 11 and 12 from the back of the segment, at the junction of the branch from the dorsal with the supra-intestinal arises a *heart* on each side. In segments 9-5 commissurals arise from the dorsal, and pass to the ventral vessels, giving branches to the ventral body-wall (Br.W.) on the way. In segment 4 this vessel from the dorsal seems to end on the alimentary canal wall, and in 6 it apparently gives off a branch, running backwards as the *lateral*, though the point of junction in the specimens examined was not very clear. The lateral runs on as the *sub-intestinal* on each side, in 10, 11 and 12 receiving branches from the alimentary canal, derived from the supra-intestinal, and ending on the posterior mesentery of segment 13.

The *ventral* is single along the whole length of the body, breaking up in segment 1, and appearing to give branches to the ventral body-wall behind the hearts.

From the foregoing description it will be seen that, as far as may be stated from the limited number of worms examined:—

1. The number of hearts seems to be fairly constant, three being the usual; but they may tend to increase as in *P. dorsalis*, *P. corii* and *P. fielderi*, the last showing this characteristic markedly. Beddard (1) remarks that the *position* of the last heart is not a character subject to variation.

2. That the hearts may be always distinguished from mere swollen vessels by their connection with the supra-intestinal, except in the case of *D. davallia*, as described.

3. That as far as can be made out from dissections there seems to be a correlation between the anterior ending of the supra-intestinal vessel and the origin of the hearts—when the former opens into the dorsal vessel at the anterior end the hearts having no connection with the dorsal; but if the supra-intestinal merely breaks up, the hearts take origin from both it and the dorsal, except in the case of *D. darallia* and *C. gippslandicus*, in which the anterior junction of the supra-intestinal and dorsal is very fine, if present. This worm, however, is aberrant in other particulars, e.g., the double dorsal vessel, so it may not be possible to place it under any generalised heading.

4. That the function of the hearts is mainly propelling, though they may give off branches, supplying organs in their course—e.g., nephridia; and the place of the ordinary one or more commissural vessels, passing from the dorsal to the ventral behind the hearts, and supplying the alimentary canal on the way, is in their region, taken by the branch from the supra-intestinal, which is in some cases very large.

5. That the supra-intestinal varies in the position of its origin, but is apparently always connected with the dorsal at or close to its hinder end.

6. That the lateral is a constant feature, though varying in its point of origin—seeming, however, most frequently to arise from the commissural vessel in segments 4 or 5. That it is not always observed to divide into a forward and a backward running portion may be due to the small size of the former, though in many it was most marked. Bourne (11), in a note on p. 62, says, "These vessels (Intestino-tegumentary), or at any rate, some having similar relations, have been stated to communicate directly with the dorsal vessel in Limbricus." In *M. coeruleus*, however, the only direct connection of the intestino-tegumentary with the dorsal, which he describes, is in the capillary network at the anterior end. The lateral usually runs on as a separate sub-intestinal on each side, but occasionally the two become united; while in some cases, as in *P. dorsalis* and *P. tenax*, at the anterior end it seems to take an important function in relation to the supply of the ventral body-wall, and presumably of the nephridia. Howes (12)

figures an infra-intestinal vessel, and Beddard (2) describes a single sub-oesophageal vessel in Acanthodrilus, while in *Typhaeus gemmii* (3) he mentions the lateral, which supply the gizzard, and run below the intestine close to each other; so that the single or double character of the sub-intestinal is evidently a variable feature.

7. There seems to be no evidence in Australian forms of the existence of the subneural vessel. Beddard (2), in reference to this structure, says (p. 473), "The subneural blood-vessel, which does not appear to be present in any genera of Oligochaeta, which have been referred to Claparede's division of the Limicolae, is also wanting in some earthworms. Perrier has denied its existence in *Portodrilus* and *Perichaeta*, and Benham states it is also absent in *Microchaeta*. It is therefore of some little importance to note that this blood vessel is not invariably absent in the genus *Perichaeta*."

8. That the general rule is for the dorsal to be a single vessel, and that even where it is double, as in *M. goonmurk* and *C. gippslandicus* the ventral is single. Beddard (4), quoting from Balfour, Comparative Embryology, vol. i., p. 282, says that the existence of a double dorsal vessel seems an embryonic character, because the single vessel in *Lumbricus* and *Criodrilus* is formed by coalescence of two vessels at first distinct. In the same paper he describes the double vessel in *Microchaeta rappi;* and in (2) one in *Acanthodrilus annectens;* also in *Acanthodrilus antarcticus* (3). There are many other recorded examples, e.g., Benham (7) in *Microchaeta papillata; Acanthodrilus haplocrystis* (8); at the anterior end of *Pleurochaeta* (9); in *Dinodrilus beddardi* (10); and others, e.g., Bourne (11).

9. That the blood supply to the alimentary canal and related structures at the anterior end is generally more or less in the form of a plexus (compare Bourne, 11), which may be associated with the much-divided structure of the salivary gland. At the hinder end the supply is simple, being mainly from the commissural vessels.

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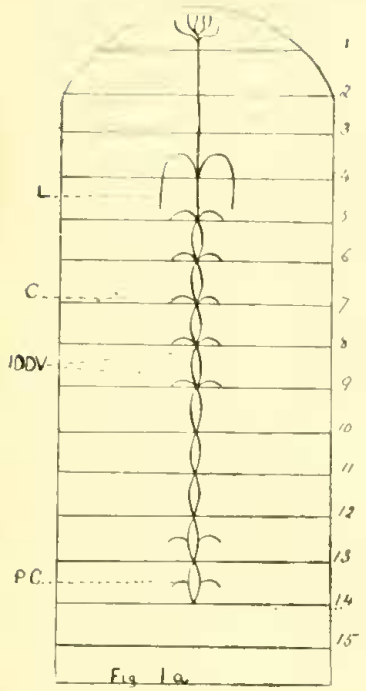


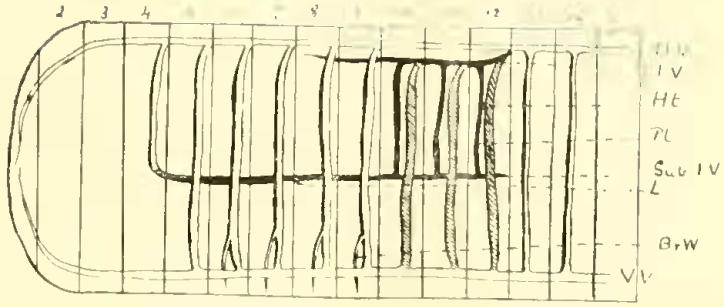


Fig 1 CRYPTODRILUS GIPPSLANDICUS

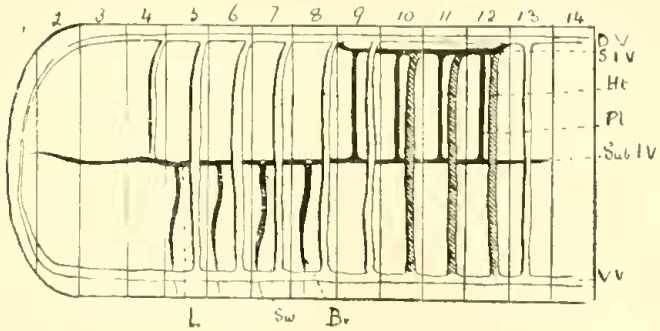
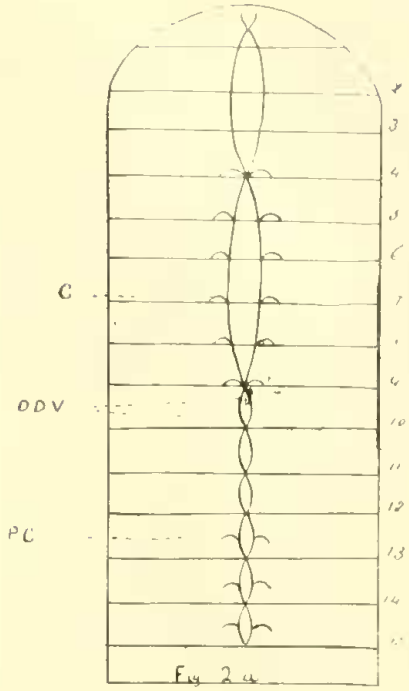


Fig 2 MEGASCOLEX GOONMURK



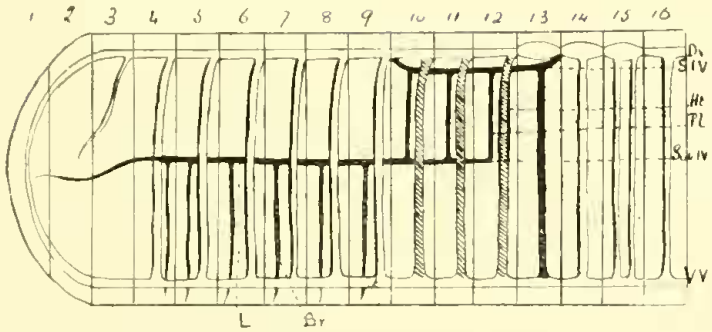


Fig 3 DIPOROCHAETA DAVALLIA

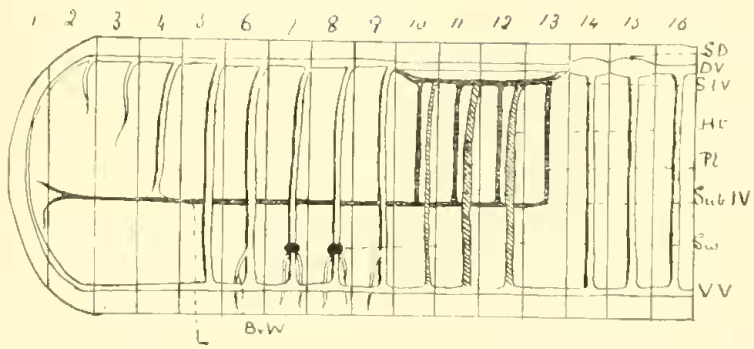


Fig 4 MEGASCOLEX TENAX

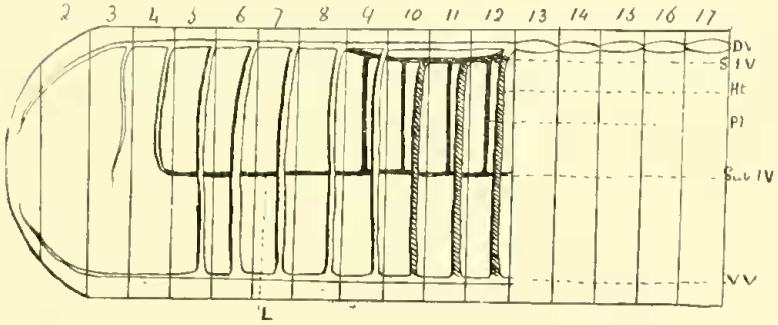


Fig 5 PERICHAETA OBSCURA

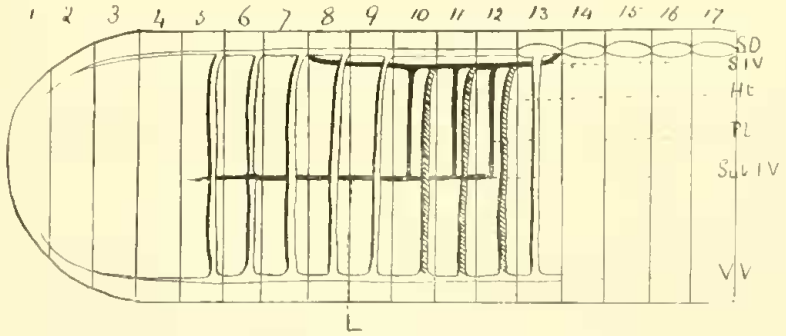


Fig 6 PERICHAETA MANNI